Matched Field Tomographic Inversion For Geoacoustic Properties

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Award #: N00014-96-1-0721

LONG TERM GOAL

The geoacoustic properties of the ocean bottom, including sound speed profiles, densities, attenuations and sediment layer depths, have a significant effect on sound propagation in shallow water. The long term goal of this work is to develop a new tomographic inversion method based on matched field processing of broadband data for estimating geoacoustic properties.

OBJECTIVES

Matched field tomographic inversion is a relatively new approach (Tolstoy, 94) that is specifically designed for rapid, high resolution estimation of ocean bottom properties. The technique makes use of multiple vertical line arrays, and extends the MF inversion method to 3-D anisotropic environments, i.e. variability in depth, range and cross-range. An experiment to obtain acoustic field data at a multi-array system was successfully carried out using broadband sound sources in the Haro Strait Primer Experiment in June 1996. Initial analysis of the data for estimation of local geoacoustic properties has been reported previously (Chapman et al., 1997). The objectives of the current study are to investigate the performance of the freeze bath method for inversion of the broadband data, and to develop an approach for inverting the range dependent data from the Haro Strait experiment.

APPROACH

An extensive broadband data set was collected in the Haro Strait Primer experiment, using light bulbs as sound sources (Chapman et al., 1997). The first step in investigating the general tomographic inversion problem was to develop a method based on waveform matching for inverting broadband data. The method employs ray theory to calculate replica fields, and uses a new approach to the global search process that is capable of estimating distributions of model parameter values that optimize the field data. This work constituted the M.Sc. thesis project of L. Jaschke (1997). In parallel with this work, an approach was designed for extending the local inversion to estimate geoacoustic properties in range dependent environments. The new method uses a segmentation scheme to separate the environment into range independent sections. The inversion is carried out segment by segment, using new data for each segment. A simulation was designed to test the approach.

WORK COMPLETED

Work was completed on the freeze bath method for estimating geoacoustic properties from broadband acoustic field data. The method was demonstrated on synthetic broadband data to simulate the signals from the Haro Strait experiment, and subsequently applied to data obtained at one of the arrays.

Report Documentation Page					*Form Approved* *OMB No. 0704-0188*
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1. REPORT DATE **1998**		2. REPORT TYPE			3. DATES COVERED **00-00-1998 to 00-00-1998**
4. TITLE AND SUBTITLE **Matched Field Tomographic Inversion for Geoacoustic Properties**					5a. CONTRACT NUMBER
					5b. GRANT NUMBER
					5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)					5d. PROJECT NUMBER
					5e. TASK NUMBER
					5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **University of Victoria,School of Earth and Ocean Sciences,PO Box 3055,Victoria, BC, Canada, V8W 3P6,**					8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)					10. SPONSOR/MONITOR'S ACRONYM(S)
					11. SPONSOR/MONITOR'S REPORT NUMBER(S)
12. DISTRIBUTION/AVAILABILITY STATEMENT **Approved for public release; distribution unlimited**					
13. SUPPLEMENTARY NOTES **See also ADM002252.**					
14. ABSTRACT					
15. SUBJECT TERMS					
16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**	**Same as Report (SAR)**	**3**	

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std Z39-18

Simulations were completed to test a new method for extending local inversion techniques to range dependent environments. The simulations showed that the new approach was computationally efficient, and the inversion performance was accurate.

RESULTS

The freeze bath method has been demonstrated on synthetic and experimental data for matched field inversion for geoacoustic properties . The method makes use of the heat bath algorithm for simulated annealing. However, unlike simulated annealing, the system is not 'cooled' to an optimal solution. Instead, the process is paused at a temperature near the annealing point, and the distribution of possible models that provide a good fit to the acoustic field data is sampled at that temperature. The method also determines an optimal set of independent parameters, based on the covariance matrix of the sampled models, and adjusts the annealing temperature adaptively to account for parameters with different sensitivities. The method is thus capable of determining correlations between geoacoustic model parameters, and providing an estimate of the error in the estimated parameter values. The method was applied to the Haro Strait data for a single light bulb and one of the arrays (Chapman and Jaschke, 1998). Estimated parameter values for the sound speed and layer thickness were consistent with ground truth data, and the estimated distributions showed which of the model parameters could be estimated reliably. In this case, the sampled distributions for the deeper layers were essentially flat, indicating poor estimation performance.

A range dependent inversion method was developed for inverting the data from multiple light bulb sources deployed radially from a vertical line array. The process involved several stages: first, the identification of the acoustic path for each component of the light bulb signals; and subseqently, the inversion of travel time and amplitude information from each of the bulbs. An efficient, automatic algorithm was designed to identify the multipath signals. The environment was segmented into sections corresponding to the locations of each of the light bulbs. The geoacoustic properties in each segment were inverted in turn, starting with the segment closest to the array, and using new data for each segment. The inversion method used a straightforward Monte Carlo search combined with a local downhill simplex algortihm. The method proved to be efficient and accurate in simulations for the broadband data for a synthetic Haro Strait environment.

IMPACT/APPLICATIONS

The freeze bath inversion method provides a meaningful error measure for the inverse problem, as well as the estimate of the optimum value. This approach holds interest for seismic as well as acoustic inversion. The range dependent tomographic inversion method provides an efficient means for estimating geoacoustic properties over an area.

TRANSITIONS

The broadband light bulb data from the Haro Strait experiment were used by collaborators from MIT in an ocean acoustic inversion of the sound speed profile over the are enclosed by the arrays (Elisseeff et al, 1997), and by researchers at the Defence Research Establishment Atlantic in an investigation of the source level of light bulb implosions (Heard et al, 1997). Also, Dr. Alex Tolstoy has used the Haro Strait concept in her simulation work, and intends to use some of the broadband data in her investigations of geoacoustic inverse methods that have been funded by ONR.

RELATED PROJECTS

This work on geoacoustic inversion is related to several other projects currently funded by ONR; I have had discussions with investigators in each project to describe the results of the Haro Strait experiment. These projects include: the Yellow Sea experiment (Peter Dahl, APL, Washington); the SHELFBREAK Primer experiment (Jim Lynch, WHOI and Kevin Smith, NPS); and the geoacoustic inversion investigations of Mediterranean Sea data by Alex Tolstoy and Peter Gerstoft.

Geoacoustic inversion using light bulb sound sources was used in the Santa Barbara Channel experiment in April 1998. I designed the deployment geometry at the request of the project leader, Dr. Newell Booth.

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